



Agricultural Memorandum No 853

R J Adams

A new Approach to Long Term Irrigation Planning

Introduction

The cost of installing irrigation equipment on a moderate sized farm is likely to be in the order of several tens of thousands of pounds, and so careful thought in the planning stage is obviously of considerable benefit - firstly to determine whether the investment is economically sound, secondly to ensure that the system when installed will actually be able to deliver the water when needed. Both of these considerations obviously require knowledge of the seasonal water requirement and its likely variation from year to year, and so the services of agrometeorologists have been frequently called upon in the past to assist in providing this information. Meteorologists have also provided the means by which a farmer can assess the current, day to day, irrigation need of particular farm, i.e. how the system is operated once installed. However except inasmuch as these determine the peak demand (operation cycle time) with which a system must cope, the short term aspects of irrigation planning are not the subject of this memorandum.

Long Term Planning - Existing Method

Methods of determining long term irrigation needs have been described in various publications, notably the 'Atlas of Long Term Irrigation Need for England and Wales' (hereafter abbreviated to ALTIN or simply 'The Atlas') by W H Hogg, and MAFF Bulletin 138 'Irrigation' (1, 2). These two publications differ in that one (the bulletin) presents data in tabular and graphical form, the other as a series of maps of England and Wales. However both adopt essentially the same approach, namely that weather data from a number of meteorological observing stations have been processed to provide estimates of potential soil moisture deficits (PSMD) at each of the observing stations. From these data was deduced the amount of water required to reduce these deficits to specific planned levels during those various periods of the year at which crops are responsive to irrigation. In the case of the Atlas, interpolation between the sites for which calculations were performed enabled maps of irrigation need to be drawn up for England and Wales as a whole. In order to present the variety of irrigation plans and periods of water application each section of the Atlas comprised 60 maps. These sections covered 'Total need (in 20 years), Adjusted total need, Need in driest year, Need in 5th driest year, No of years with irrigation need', making a total of 300 (5 x 60) maps in all. The graphical presentation of Bulletin 138 required 12 diagrams and about 20 pages of tables to display a selection of similar information.

The requirement for such a large amount of data stemmed from the need to cover (as nearly as possible) all the different farm circumstances and locations which could arise. Thus when a particular farmer was seeking guidance on the water requirement of his farm, somewhere or other a map, table or graph could hopefully be found to provide the information.

In general, such an approach can be reasonably effective. However, there is now a need to revise these existing documents because firstly they have to be presented in metric rather than imperial units, and secondly, certain developments have taken place in the understanding of the relationships between meteorological factors and the water loss from crops. We should therefore ask the question

'Should the calculations that these changes have made necessary be applied to the existing approach, or are there reasons to favour a more fundamental re-appraisal of the system as a whole? In order to answer this question we must consider some of the disadvantages of the existing system:-

i. Even with 300 maps (ALTIN) or 30 tables and graphs, only 4 basic irrigation plans are covered. These are:-

Plan 1	Apply 25 mm of water at 25 mm SMD
2	50 mm 50 mm
3	50 mm 75 mm
4	75 mm 125 mm

It is not uncommon to find (even in Bull.138) recommendations to irrigate according to plans not included in the above group. e.g. Apply 25 mm at 50 mm SMD. To some extent intelligent interpolation between the maps can provide a not unreasonable answer, but it is no easy matter, even for the experienced user, to estimate the magnitude of the errors which this approximation generates.

ii. Farms frequently have more than one soil type and grow a number of crops which are managed on a rotation system. Thus one finds that for a given field or crop, the irrigation plan may not remain constant from year to year, a complication with which the Atlas & Bulletin cannot cope, since any individual map or diagram is based on the varying needs over a 20 year period for one irrigation plan.

iii. Most crops need irrigating differently at different stages of growth (e.g. at flowering and before harvest, but not in between), so an irrigation plan may appear as 'follow Plan 1 during April to May and Plan 2 July to August'. Even if the plan is the same for both periods a difficulty for the reader arises from the presentation of the data in the form 'need in driest year, need in 5th driest year', because the year in the sample of 20 which contained the driest April and May at a particular site, may not have been the same year as contained the driest July and August.

The same difficulty arises from the fact that an irrigation need is expressed as the additional water required to contain a deficit within the planned limit, once the soil has been returned to field capacity at the start of the irrigation period (even if the actual operation of the plan does not require this). At the start of irrigation in any particular year, this additional amount clearly depends on the soil moisture deficit which has by then developed, which is a function of the preceding weather. Thus the complication again arises that (say) the driest August and September may have been preceded by the wettest April to July, or the driest, or any one of the other 18 possibilities. What then is the meaning of 'the fifth driest year'? Incidentally although the point is made quite clear in the introduction to the Atlas (not so in the Bulletin) it is a rarity to find a user of either of these documents who is aware of the 'return to field capacity' basis of the calculations.

iv. The basis for calculation of soil moisture deficits assumes that water loss from the crops will proceed at the full potential rate, with no modification for reduced crop cover.

v. The local rainfall and transpiration rates applicable to the farm may be considerably different from those which the interpolation of SMD's calculated for the meteorological stations would imply.

vi. Neither the Atlas nor the graphical presentation indicate the peak short term demand, for which pipework and other equipment must be designed.

For the straightforward case of a requirement to assess the long term water need for a farm with one irrigated crop and one soil type, the existing methods can provide most of the basic (meteorological) data on which planning decisions should be based. (Provided of course that the user is fully aware of the principles on which the calculations are based and the manner in which the data should be used).

For the more commonly arising situation, in which soils vary, crops rotate, plans do not correspond exactly with those presented, etc, long term water requirements can only be produced by making so many generalisations that the accuracy of the result must be in some doubt. Of course, it is fair to say that the overall results will probably be about right in most cases, but such an assessment hardly justifies the amount of effort and scientific thought which went into the compilation of the Atlas in the first place.

In conclusion of this appraisal of the existing approach we must point out that the compiler of the Atlas was aware of its shortcomings and in fact drew attention to these in his introduction. At the time of compilation (1965-67), many facilities now in everyday use were not then available i.e. the manner in which the author chose to present the data was the most suitable at that time.

The most significant restriction imposed upon the author of the Irrigation Atlas arose because the potential users did not at that time have easy access (eg through computer links) to the computer stored data and programs on which the SMD calculations were based. Therefore the data had to be presented in as complete a form as possible, i.e. as already computed irrigation needs - in the hope that the range of circumstances covered was sufficiently varied that any individual farm could subsequently be made to 'fit'. Clearly, a far more satisfactory approach would be to start with the farm and then calculate the SMD's and irrigation needs for each year, tailored to the particular circumstances of that farm.

With this approach, virtually every one of the disadvantages listed for the existing method is either eliminated or greatly reduced. This includes the elimination of the 'driest year in 20' type of term, which can be replaced by 'greatest irrigation need in years sampled'.

There were at least two other reasons why, in the 1960's, Hogg did not choose to follow the proposed 'farm first, calculation afterwards' approach. Firstly, the calculation of 20 year moisture balance sheets for over 70 stations was a substantial task. (Although alleviated to some extent by the fact that the author had been compiling such data for a number of years.) To calculate the same type of data for every farmer who might contemplate irrigation, as a 'one off' exercise, was impractical. Secondly, a further requirement of the Atlas or bulletin was to provide a means of comparing the relative feasibility of providing irrigation in different parts of the country. For this purpose, the Atlas is still a very useful document, as are the diagrams such as Figures 24-35 in Bulletin 138.

Proposed Approach

As already indicated, the essence of the proposed approach is 'farm first, calculation afterwards'. However, although it would be possible to calculate the required daily balance sheets for the specific farm from the basic weather data recorded at the nearest meteorological station(s), it is more practical to introduce an intermediate stage of data preparation. This involves the compilation (at Meteorological Office HQ Bracknell) of a data bank in which daily values of potential evapotranspiration (PE) have been calculated for all parts of the UK and stored, together with daily values of rainfall, for a period of (say) 20 years. In practice it may turn out to be advantageous to store the data in a more fundamental form than PE, but the important points are:-

- i. The user does not have to seek out suitable long term meteorological stations representative of the individual farm each time a request for irrigation planning is received - that operation will, in effect, have already been done. The user has only to specify in which 20 x 20 km (MORECS) grid square the farm lies.
- ii. The stored data has not yet been converted into an irrigation plan, nor even a SMD, because both of these depend on the circumstances of the individual farm.

Once the basic data bank has been compiled, and an appropriate computer program written, it will be possible to calculate SMD's for the individual farm. The computer will print a table showing on which days irrigation would have been required to reduce the deficit to the planned level. Thus any irrigation plan may be specified, including if necessary, periods when irrigation is not needed, and changes in plan as the growing season progresses.

Besides the elimination of the disadvantages of the existing approach, certain other positive advantages accrue from the use of the proposed method, generally due to the relative ease with which users will be able to gain access to it.

i. By transferring the data and program to the MAFF computer at Guildford, the estimates of long term irrigation need for a particular farm can be made through the terminals at ADAS Regional Centres. In fact, given the appropriate input data, the actual running of the program could be achieved by anyone with the ability to operate a terminal connected to the Guildford computer. The precise nature of the input data and the interpretation of the results, would of course still require the services of the local Advisory Officers, and the Agrometeorologist. In addition, the guidance of the latter would certainly be required to assess whether the data computed for the appropriate grid square should be modified to make them representative of the farm itself. The basic grid square values will be computed for the average (or average agricultural) height of the square, and so the PE and rainfall data should be modified according to the height of the farm.

ii. On the basis of an irrigation need assessment a Water Supply Officer would be able to draw up a preliminary plan, based on his expertise in system design and of local water availability and quality. The feasibility and cost of achieving the specified water demand can then be assessed. If necessary, the program can be re-run using different values for the input parameters, enabling the adviser to estimate the effect upon water demand of changing the command area, crop variety or rotation system. (See Figure 1). From the wider point of view of the researcher or farm management adviser, this suggested approach enables the sensitivity of irrigation costs to the various imposed restraints to be deduced.

iii. The third additional advantage is perhaps more obscure but in practical terms is nevertheless very real. If the computer program is constructed as a series of subroutines then changes may be made either to these or the basic data at any time without the need to rewrite the instructions for their use i.e. the programmer may introduce improvements (say through advances in knowledge of the principles involved) without the user having to learn a new technique, and without the need to revise published data which might otherwise have become out of date. As has already been pointed out, the Irrigation Atlas, even if it had been perfect in all other ways, would now require reworking for this very reason.

Conclusion

It must be remembered that the existing long term irrigation planning methods outlined in the existing Bulletin 138 and the Irrigation Atlas retain their

value for 'first look' assessments, or to make generalised comparisons between water needs in different parts of the country. Thus the service proposed here should be seen as an addition to, rather than a complete replacement of that which exists.

For more detailed assessments, the proposed approach to long term irrigation planning offers a more flexible, accurate, and easier to use system than that at present in operation. Some features are available which the existing methods do not provide at all, and because the analysis can be seen to be based right from the start on the particular circumstances of the farm under study, the approach may be expected to have a distinct psychological appeal to the farmer. The 'feed back' facility by which preliminary plans can be modified probably constitutes the biggest attraction to the adviser.

Looking ahead, if the other, non meteorological disciplines, (e.g. water supply, agronomy, farm management) can adopt a similar computerised approach, we should expect to see the work described in this memorandum as just one part of the study of irrigation planning. If the technique proposed here is adopted, the adviser will be better able to answer the question 'If I have an irrigation system installed, how much water will I need?' However, what the farmer is more likely to ask is 'If I have irrigation installed, will the (supposedly) increased yields be sufficient to make the operation cost effective?' The interaction of the various constraints influencing the latter question can be assessed by using exactly the same approach as was needed to answer the former.

Meteorological Office
ADAS Cambridge

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The author would be pleased to receive any comments or suggestions concerning the contents of this memorandum.

References

1. W H HOGG. Atlas of Long-Term Irrigation Needs for England and Wales. M.A.F.F. 1967.
2. Bulletin 138 'Irrigation'. Fourth Edition MAFF 1974.

Preliminary

Met. Office H.Q.
(Met. O. 8) prepare
Data bank. PE, RR values
over 20 year period for
each 20 x 20 km MORECS
square.

AAO, HAO visits farm.
Obtains input data.
Location, soil, crop
rotation, command area.
Approx. dates for
planting etc.

Agrometeorologist assesses
need for site modifications
to meteorological data.

Program written to calculate
SMD and irrigation to correct

Run Program

Program output:
Irrigation required each
year of sample,

Time of 1st application,
Total need,
Minimum time between
applications,
Maximum short period
demand.

Adjust input values
e.g. irrigation plan,
cropping,
Command area.

DWSO, Mechanisation Adviser
produce system design.
Assess cost, Water Availability

Advisers,
Agrometeorologists,
farmer etc discuss
project.

Cost OK?
Water Available
?

NO

YES

FINISH

Figure 1

Long Term
Irrigation
Planning

Suggested
Stages in
system design